

4/12/82
1 distribution information, and a recognition/judgment computer
2 30 for detecting three-dimensional positions of roads and solid
3 objects at high speeds based on the distance information inputted
4 from the image processor 20, for identifying a preceding vehicle
5 or an obstacle based on the result of the detection and for judging
6 whether or not an alarm should be issued to avoid a collision
7 with the preceding vehicle or the obstacle.

8 The recognition/judgment computer 30 is connected with
9 sensors such as a vehicle speed sensor 4, a steering angle sensor
10 5 and the like in order to detect a present traveling condition
11 of the vehicle and also it is connected with a display 9 provided
12 at the front of a vehicle driver for informing hazard. Further,
13 the computer 30 is connected with an external interface for
14 example for controlling actuators (not shown) which operate so
15 as automatically to avoid a collision with the obstacle or the
16 vehicle traveling ahead.

17 The stereoscopic optical system 10 is composed of a
18 pair of left and right CCD (Charge Coupled Device) cameras 10a,
19 10b. A pair of stereoscopic images taken by the CCD cameras 10a,
20 10b are processed in the image processor 20 according to the
21 principle of triangulation to obtain three-dimensional distance
22 distribution over an entire image.

23 The recognition/judgment computer 30 reads the
24 distance distribution information from the image processor 20
25 to detect three-dimensional positions with respect to the
26 configuration of roads and solid objects such as vehicles and
27 obstacles at high speeds and judges a possibility of collision
28 or contact with these detected objects based on the traveling

1 condition detected by the vehicle speed sensor 4 and the steering
2 angle sensor 5 of the self vehicle to inform the vehicle driver
3 of the result of the judgment through the display 9.

4 Fig. 2 shows a constitution of the image processor 20
5 and the recognition/judgment computer 30. The image processor
6 20 comprises a distance detecting circuit 20a for producing
7 distance distribution information and a distance image memory
8 20b for memorizing this distance distribution information. More
9 specifically, the distance detecting circuit 20a calculates a
10 distance to a given object by selecting a small region imaging
11 an identical portion of the object from the left and right
12 stereoscopic images taken by the CCD cameras 10a, 10b,
13 respectively and then obtaining a deviation between these two
14 small regions and outputs in the form of three-dimensional
15 distance distribution information.

16 Fig. 9 shows an example of either of images taken by
17 the left and right CCD cameras 10a, 10b. When this image is
18 processed by the distance detecting circuit 20a, the distance
19 distribution information outputted from the distance detecting
20 circuit 20a is expressed as a distance image as shown in Fig.
21 10.

22 The example of the distance image shown in Fig. 10 has
23 a picture size composed of 600 (laterally) x 200 (longitudinally)
24 picture elements. The distance data are included in white dotted
25 portions that correspond to the portions having a large difference
26 of brightness between two adjacent picture elements aligned in
27 the left and right direction respectively in the image shown in
28 Fig. 9. Further, in this example, the distance detecting circuit

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1 20a treats the distance image as an image composed of 150
2 (laterally) x 50 (longitudinally) blocks, i.e., 4 x 4 picture
3 elements for one block or one small region. The calculation of
4 distance is performed for each block of the left and right images.

5 The recognition/judgment computer 30 comprises a
6 microprocessor 30a primarily for detecting the road configuration,
7 a microprocessor 30b primarily for detecting solid objects based
8 on the configuration of a road detected and a microprocessor 30c
9 primarily for identifying a preceding vehicle or an obstacle based
10 on the positional information of the detected solid objects and
11 for judging a possibility of collision or contact with the
12 preceding vehicle or the obstacle and these microprocessors 30a,
13 30b, 30c are connected in parallel with each other through a system
14 bus 31.

15 The system bus 31 is connected with an interface circuit
16 32 to which the distance image is inputted from the distance image
17 memory 20b, a ROM 33 for storing a control program, a RAM 34 for
18 memorizing miscellaneous parameters produced during
19 calculations, an output memory 35 for memorizing the result of
20 processing, a display controller 30d for controlling the display
21 9 and an I/O interface circuit 37 to which signals are inputted
22 from the vehicle speed sensor 4 and the steering angle sensor
23 5.

24 As shown in Fig. 9, the distance image has a coordinate
25 system composed of a lateral axis i, a longitudinal axis j and
26 a vertical axis dp with an origin of the coordinates placed at
27 the left below corner of the distance image. The vertical axis
28 dp indicates a distance to an object which corresponds to the

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1 final strip. The program goes from S128 to S130 where it is
2 investigated whether or not the process reaches the final group.
3 When the process does not yet reach the final group, the data
4 of the next group are read and hereinafter the same processes
5 are carried out repeatedly. When the process reaches the final
6 group, the division of the groups is completed and the program
7 goes from S130 to S132.

8 The following steps S132 to S137 are of processes in
9 which further classifications of "side wall" or "object" are
10 carried out to raise the accuracy of the classification performed
11 at S127. After the data of the first group are read at S132, at
12 S133 approximate straight lines are obtained from the positions
13 (X_i, Z_i) within the group according to the Hough transformation
14 or the linear square method to calculate a gradient overall the
15 group.

16 Then, the program goes to S134 where the group is
17 reorganized such that the group having a gradient inclined toward
18 X-axis is classified into the "object" group and the group having
19 a gradient inclined toward Z-axis is classified into the "side
20 wall" group. Further, at S135, miscellaneous parameters of the
21 group are calculated. With respect to the group classified
22 "object", these parameters include an average distance which is
23 calculated from the distance data within the group, X-coordinates
24 at the left and right ends of the group and the like and with
25 respect to the group classified "side wall", those parameters
26 include an arrangement direction of the data (gradient with
27 respect to Z-axis), Z, X coordinates of the front and rear ends
28 of the group and the like. In this embodiment, in order to raise

1 position and the X-coordinates thereof are determined according
2 to the procedure which will be described hereinafter.

3 At S202, a node N_i corresponding to an end point on the
4 vehicle side of the selected side wall group is established based
5 on the Z-coordinate of the end point and the X-coordinate of the
6 node N_i is established being adjusted to the X-coordinate of the
7 end point. Next, the program goes to S203 where the next node
8 N_{i+1} is established in the direction of the gradient of the side
9 wall group. Next, when the node N_{i+1} ($i \geq 2$) is determined, its
10 direction is established along a direction of the second previous
11 node.

12 Then, the program goes to S204 where, as shown in Fig.
13 15, the position of the wall surface is searched by a so-called
14 "pattern matching" within a specified searching range to extract
15 a solid object P_i for every strip within the searching range. For
16 example, the searching range in the X-axis direction has ± 3 to
17 5 meters in the X-axis direction and ± 1 meter in the Y-axis
18 direction with its center placed at a coordinate (X_{Ns+1}, Z_{Ns+1}) of
19 the node N_{s+1} established at S203.

20 The matching of the wall surface pattern is performed
21 to the solid object P_i within the searching range. Fig. 16 shows
22 an example of the wall surface pattern (weight coefficient
23 pattern) used for the pattern matching. The wall surface pattern
24 shown in Fig. 16 is a pattern for the wall surface on the left
25 side and a symmetric pattern to this pattern is used for the wall
26 surface on the right side. The lateral axis of this wall surface
27 pattern coincides with the distance in the X-axis direction and
28 the longitudinal axis indicates a weight coefficient. A maximum

1 on the right side. In the example shown in Fig. 14, the wall surface
2 from the 9th node to the 26th node is detected on the right side
3 of the self vehicle and the 9th node is denoted as the start point
4 N_s and the 26th node is denoted as the end point N_e . These nodes
5 are used for later processes as effective nodes.

6 Thus processed position of the wall surface is further
7 corrected by a program shown in Fig. 7 and Fig. 8 using new data
8 obtained from programs shown in Fig. 3 through Fig. 5.

9 The programs shown in Fig. 7 and Fig. 8 is a program
10 for correcting the wall surface. At S301, it is investigated
11 whether or not the start point N_s of the effective nodes is larger
12 than the first node N_1 of the wall surface model. When $N_s = N_1$,
13 the wall surface has been already detected up to the first node
14 N_1 , the program skips to S306. When $N_s > N_1$, the program goes to
15 S302 where the previous node N_{s-1} ($i = 1, 2, 3$ etc.) is established.
16 Then, at S303 the wall surface pattern is searched and at S304
17 the X-coordinate of the wall surface is determined based on the
18 result of searching.

19 Next, the program goes from S304 to S305 where it is
20 investigated whether or not the process has reached the first
21 node. If not yet reached the first node N_1 , the steps S302 to S304
22 are repeated to continue the searching of the wall surface
23 position up to the node N_1 . When the processes up to the first
24 node N_1 are finished, the program goes to S306 where it is checked
25 whether or not the end point N_e of the effective nodes is smaller
26 than the last node N_{n_0} of the wall surface model (for example,
27 node N_{41} in case of the wall surface model constituted of 41 nodes).

28 As a result of this, when $N_0 = N_{s0}$, that is, the wall

1 surface has been already detected up to the last node, the program
2 skips from S306 to S311. When $N_e < N_{ee}$, the program goes from S306
3 to S307 where the node N_{e+1} after the end point N_e is successively
4 established and further at S308 the pattern matching of the wall
5 surface is performed. According to the result of the pattern
6 matching, at S309 the X-coordinate of the wall surface is
7 determined and then at S310 it is checked whether or not the process
8 has reached the last node N_{ee} . The matching of the wall surface
9 position is continued until the last node N_{ee} and when the processes
10 up to the last N_{ee} is finished, the program goes to S311.

11 These processes of establishing the nodes, the matching
12 of the wall surface pattern and the determination of the X-
13 coordinate at the steps S302 to S304 and the steps S307 to S309,
14 are the same as the processes at the steps S203, 204 and S205
15 in the aforementioned program of the wall surface detecting
16 process.

17 The processes after S311 are for correcting the
18 position (X-coordinate) of respective nodes from the first node
19 N_1 to the last node N_{ee} . First, at S311 the data of the first node
20 N_1 is set and the program goes to S312. The processes from S312
21 to S321 are repeatedly carried out by successively setting the
22 data of the next node.

23 At S312, the wall surface at the node N_1 is searched
24 and at S313 it is checked whether or not the wall surface is
25 detected by the pattern matching. If it is judged that the wall
26 surface is detected, the program goes from S313 to S314 where
27 it is investigated whether or not the difference between the
28 position X_{pw} of the wall surface and the position X_{n1} of the node

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